Review

Knowledge gaps and conservation priorities for west African chelonians

Pearson McGovern¹,*, Luca Luiselli²,³,⁴

¹ - African Chelonian Institute, Ngazobil, Senegal
² - Department of Zoology, Faculty of Sciences, University of Lomé, Lomé, Togo
³ - Department of Applied and Environmental Biology, Rivers State University of Science and Technology, Port Harcourt, Rivers State, Nigeria
⁴ - IDECC – Institute for Development, Ecology, Conservation and Cooperation, 00144 Rome, Italy

*Corresponding author; e-mail: pearsonmcg21@gmail.com

ORCID iDs: McGovern: 0000-0003-0562-1634; Luiselli: 0000-0001-6878-2916

Received 26 September 2022; final revision received 12 April 2023; accepted 18 April 2023; published online 24 April 2023; published in print 5 May 2023

Associate Editor: Sylvain Dubey

Abstract. Defining priorities is important both in research and in conservation, especially when knowledge gaps are hindering successful management. In this review, we quantify the knowledge gaps for all non-marine West African chelonians based on 21 criteria. Additionally, we combine these knowledge gaps with each species’ maximum size, range size, presence in nationally protected areas, and IUCN Red List or TFTSG provisional status to introduce a ranking of species conservation priority in the region. Our analyses revealed a divergence between which species are lacking research studies and which would benefit most from conservation actions, though Cyclanorbis elegans is the species that is both the least-known and most-in-need of conservation. Broadly, Pelomedusidae are in the greatest need of research, yet they are also collectively the least threatened. Conversely, Trionychidae and Testudinidae have received greater research attention in most cases, however, these two families represent the greatest conservation priorities amongst West African chelonians. Our analyses also enabled us to evaluate which criteria representing aspects of chelonian biology have been most overlooked by the scientific community. Priorities for future research include reproductive and long-term population studies, each of which are critical for informing conservation actions and evaluating the results of those actions.

Keywords: conservation, knowledge, priorities, research, turtles, West Africa.

Introduction

Prioritizing certain conservation actions or species over others can be difficult (Mace et al., 2007; Arponen, 2012). Known as the ‘conservation resource allocation problem,’ identifying how to allocate limited resources and how to adjust to inefficient logistics is commonplace in conservation (Wilson et al., 2006). Ultimately, decisions must be made as to which places and species most warrant protection. As such, there have been various attempts to identify priority areas more broadly (Buhlmann et al., 2009; Bombi et al., 2011; Mittermeier et al., 2015; Ennen et al., 2020), as well as priority species more specifically (Luiselli, 2009; Bombi et al., 2013), that best represent ‘conservation value’ on a scale of aesthetical to evolutionary considerations.
In most cases, after accounting for the various considerations of the involved stakeholders, the ultimate decision to conserve something is based on its level of threat (Abram et al., 2015; Tulloch et al., 2015). The trend to place greater conservation focus and effort into species experiencing greater levels of threat is logical under the assumption that threatened species will have dwindling populations and thus be more likely to disappear, if nothing changes. While this method for selecting conservation priorities makes logical sense, it can only be successful if certain basic data are available for the species or the area being conserved.

Research provides the data and the background knowledge on which conservation decisions should be based (Hu et al., 2019). In fact, there is an inextricable link between the amount and rigor of research into the biology, ecology, or life history of a species and the success of conserving that species (Southwell et al., 2017; Hu et al., 2019; Wood et al., 2020). Critical knowledge gaps can greatly hinder conservation and management actions and deciding to enact strategies before, or without, addressing these gaps may be ill-advised and wastefully expensive.

In West Africa, one group of species greatly suffering from both a lack of scientific knowledge as well as highly threatened status are the chelonians (turtles and tortoises) (Luiselli et al., 2021a). Because of their relatively little-known habits and threatened status, West African chelonians are ideal models for uncovering knowledge gaps and analyzing their effect on conservation priorities. In this review, we include 13 species of tortoise and freshwater turtle as part of the West African non-marine chelonian fauna (TTWG, 2021; fig. 1; all species natively distributed between Mauritania and Nigeria), including six freshwater species in the family Pelomedusidae (Pelusios adansonii, Pelusios castaneus, Pelusios cupulatta, Pelusios niger, Pelomedusa olivacea, Pelomedusa variabilis), three species of soft-shell turtle in the family Trionychidae (Trionyx triunguis, Cyclanorbis elegans, Cyclanorbis senegalensis), and four terrestrial species in the family Testudinidae (Centrochelys sulcata, Kinixys erosa, Kinixys homeana, Kinixys nogueyi). We also chose to present data for the previously monotypic species Pelomedusa subrufa sensu lato (TTWG, 2014) because of the ongoing taxonomic work on this debated “species complex” (Petzold et al., 2014; Nagy et al., 2015; according to TTWG (2021), Pelomedusa subrufa sensu stricto does not occur in West Africa). Finally, we did not include Pelusios gabonensis in our analyses as it is likely that old records from West Africa refer to the morphologically similar P. cupulatta, which was only formally described in 2003 (Bour and Maran, 2003; TTWG, 2021).

As is the case globally, many of West Africa’s chelonians are experiencing a multitude of threats, ranging from an ever-present bushmeat trade to habitat loss and fragmentation (Lawson, 1993, 2000; Luiselli and Akani, 2003). As such, four of the 13 turtle species in West Africa are considered as Vulnerable, two as Endangered, and two as Critically Endangered by the International Union for the Conservation of Nature (IUCN, 2022) or by the TFTSG (Tortoise and Freshwater Turtle Specialist Group of the IUCN). In response to the widespread endangerment of these species, scientists have attempted to set conservation priorities by (i) assessing species-specific threat levels (Luiselli, 2009), (ii) identifying areas in need of protection that most benefit turtles and tortoises (Bombi et al., 2011, 2013), and (iii) qualitatively recommending measures to mitigate ongoing threats (Luiselli et al., 2021a). To supplement the findings and suggestions of these authors, we quantitatively reviewed the level of knowledge for each West African turtle and tortoise species and incorporated this ‘research score’ into an overall ‘conservation priority score’ for all species (following the methodology in Forero-Medina et al., 2016).
Evidently, there are a variety of methods to assess the level of knowledge on a certain species, such as totaling all available publications or the amount of written text for a given species (Lovich and Ennen, 2013) or counting the number of publications for each species characterized by research type and topic (Stevenson, Guzman and Deffler, 2010). Here, we decided to follow the methodology of Forero-Medina et al. (2016) to best address specific research gaps for all West African chelonians, also allowing us to make intercontinental comparisons. By assigning all publications (see methods for included publications) available for each species to certain selected criteria of ecology, biology, life-history, and genetics, we uncover the research gaps hindering conservation initiatives.

Given the relationship between research and conservation, we also formulated a more comprehensive conservation priority score, in addition to the ‘research score,’ that incorporates research as a component of the total. There are other factors that must be acknowledged when determining the overall need to protect one species over another because species can experience variable pressures at differing rates over vastly different spatial scales. One of the factors that has been implicated in the level of exploitation of certain turtle species is size (Luiselli, 2009). The larger the species, the more likely it is to be encountered, selectively collected,
sold and consumed by humans (Kuchling, 1988; Luiselli et al., 2003; Maran, 2006). Another factor used in previous priority assessments for turtles is endemcity or range size (i.e., the size of their area of occurrence; Luiselli, 2009; Forero-Medina et al., 2016). While there are no turtle species endemic to any single country in West Africa (TTWG, 2021), several species are only found in certain restricted ecosystems and thus have limited ranges (i.e., *K. homeana*, *P. cupulatta*, *P. niger*) in comparison to others (i.e., *C. sulcata*, *T. triunguis*, *P. olivacea*). The vastness of the distribution of a species greatly affects its level of threat due to the likelihood that threats are less concentrated across a larger range (Bland, 2017). While it is likely that there is a correlation between the size of a species’ range and the probability that it is present in a nationally protected area (e.g., a National Park), we also included ‘Presence in protected area’ as a component of the total conservation priority score for each species to ensure that a species’ representation in one or more protected areas is represented in its overall threat level. The final, and most heavily weighted, component of the total score is the current conservation status of each species according to its IUCN (2022) Red List category. When an IUCN status for a species was either not available or outdated, we substituted it with the TFTSG provisional status for the species (TTWG, 2021).

**Methods**

To create a research score for each of the 13 West African non-marine chelonian species, we followed the methodology of Forero-Medina et al. (2016) with minimal modifications. Forero-Medina et al. (2016) used 21 criteria to identify research priorities for Colombian chelonians (table 1). We also selected 21 research criteria but chose to include ‘Diet’ as a research criterion instead of “Presence in protected areas” (instead we included this criterion directly in our overall conservation priority scores). We also included a slight modification to the definition of the ‘Population dynamics’ criterion to also consider long-term studies (>1 year) of population structure. As done in Forero-Medina et al. (2016), each species received a binary code for each criterion; a value of 1 was assigned if there was at least one published study on that criterion, and a value of 0 if there were no studies on that criterion. We then scored each species using the total number of studied criteria, for a potential maximum research score of 21. We accepted studies that were published as scientific peer-reviewed articles, books or book chapters, theses and dissertations, as well as those published in one of the chelonian specific magazines *Manouria*, *Testudo*, *Chéloniens*, *Emys*, *Radiata*, or *La Tortue*. Our reason for including these magazines is the historically widespread use of these outlets by English-as-a-foreign-language (EFL) authors when presenting valuable observations on poorly known taxa (including the description of a new species, *Pelusios cupulatta*; Bour and Maran, 2003). We did not include company or governmental reports (including Traffic and CITES), or technical reports (though the *Kinixys Conservation Blueprint* (Mifsud and Stapleton, 2014) earns special mention as a valuable comprehensive assessment of the genus *Kinixys*, produced, supported, and revised by many of the world’s experts on the genus). Finally, we did not include any unpublished data presented in IUCN-TFTSG Chelonian Research Monographs species accounts. We accepted data from anywhere within the native range of each species (except for the ‘Ex situ studies’ criterion). Though not all sources are directly cited in the text, each study used to satisfy each criterion for each species is provided in the literature cited section of this publication. While there were many cases in which several studies could have been chosen to represent a criterion for a given species, our analysis only required one study for each criterion to be considered “covered.” In other cases, there was only a single study for a given criterion, in which case that study
Table 1. Criteria used for the classification of the level of published knowledge of the continental turtles of West Africa based on criteria previously used by Forero-Medina et al. (2016). Deviations from Forero-Medina et al. (2016) include the addition of “Diet” as a criterion, the inclusion of population structure within the definition of the ‘Population dynamics’ criterion, and the removal of “Presence in protected areas” as a research criterion.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geographic distribution</td>
<td>Quantitative models of geographic distribution.</td>
</tr>
<tr>
<td>Population estimates</td>
<td>Measures of density or abundance estimated with statistical models (mark-recapture, distance methods, etc.).</td>
</tr>
<tr>
<td>Abundance (index)</td>
<td>Estimate of relative abundance (indices, catch per unit effort).</td>
</tr>
<tr>
<td>Home range</td>
<td>Estimate of home range area (GPS, radiotelemetry, mark-recapture, thread-tracking, etc.).</td>
</tr>
<tr>
<td>Habitat (quantified)</td>
<td>Quantitative evaluation (not descriptive) of habitat (use, preference, etc.).</td>
</tr>
<tr>
<td>Population dynamics</td>
<td>Studies longer than 1 year evaluating population parameters, structure and size.</td>
</tr>
<tr>
<td>Growth</td>
<td>Studies on growth (in situ).</td>
</tr>
<tr>
<td>Size or age at sexual maturity</td>
<td>Mention of age or size at sexual maturity (in situ).</td>
</tr>
<tr>
<td>Longevity, generation time</td>
<td>Field studies that evaluate longevity or mean time between two consecutive generations.</td>
</tr>
<tr>
<td>Sex determination</td>
<td>The mechanism of sex determination is known specifically for the species.</td>
</tr>
<tr>
<td>Number of clutches per season</td>
<td>Studies that determine the number of clutches or nests per female per reproductive season, or year if reproduction is continuous.</td>
</tr>
<tr>
<td>Clutch size</td>
<td>Field studies on average clutch size.</td>
</tr>
<tr>
<td>Interannual nesting frequency.</td>
<td>Field studies that evaluate whether a female lays eggs every year, or with what frequency they nest (annual, biannual, etc.).</td>
</tr>
<tr>
<td>Survival rate</td>
<td>Field studies over multiple seasons or sites that evaluate the survivorship of different age, sex, or size classes.</td>
</tr>
<tr>
<td>Diet</td>
<td>Field studies on the diet of the species in its native range.</td>
</tr>
<tr>
<td>Effect of anthropogenic activities</td>
<td>Studies that evaluated the impact of a human activity on some population of a species (hunting, contamination, pet-trade, etc.).</td>
</tr>
<tr>
<td>Studies ex situ</td>
<td>Studies on the biology or behavior of a species in captivity.</td>
</tr>
<tr>
<td>Phylogenetic rarity</td>
<td>Studies that determine the phylogenetic uniqueness or distinctiveness of a species (e.g., phylogenetic studies).</td>
</tr>
<tr>
<td>Evolutionary significant units (ESU)</td>
<td>Studies that determine ESUs for a species (e.g., phylogenetic and phylogeographic studies).</td>
</tr>
<tr>
<td>Management units (MU)</td>
<td>Studies that determine Mus for a species (e.g., phylogenetic or population genetic studies).</td>
</tr>
<tr>
<td>Genetic diversity and molecular</td>
<td>Studies that evaluate genetic diversity using molecular tools in order to examine demographic or ecological information, such as multiple paternity, natal philopatry, population expansion, bottlenecks, or genetic drift at different spatiotemporal scales (i.e., studies of phylogeny, phylogeography, population genetics, and molecular ecology).</td>
</tr>
<tr>
<td>ecology</td>
<td></td>
</tr>
</tbody>
</table>

represents everything that is ‘known’ on that topic for that species. Some studies covered several criteria and/or several species (i.e., nearly all K. homeana studies also include data for K. erosa; Lawson, 2000, 2006; Luiselli, 2003, 2006; Akani et al., 2004; Cayuela et al., 2019).

Using this scoring system, a low research score represents a species in greater need of research. We then combined each species’ research score with species-specific scores on maximum size, range size, IUCN (2022) or TFTSG status, and presence in protected areas to create an overall conservation priority score for each species. Conservation priority scores were weighted based on presumed importance, with IUCN (2022) Red List or TFTSG threat status being considered the most important (0.4), followed by range size (0.2), maximum size (0.2), research priority (0.1), and presence in protected areas (0.1). For the IUCN (2022) Red List or TFTSG status score (whichever presented a higher threat category; TTWG, 2021), each species was scored on the following scale: Critically Endangered (CR) = 1, Endangered (EN) = 2, Vulnerable (VU) = 3, Data Deficient (DD) = 3, Near Threatened (NT) = 5, Least Endangered (LE) = 6.
Table 2. Scores for each species and each criterion used to assess conservation priorities for West African chelonians.

<table>
<thead>
<tr>
<th>Species</th>
<th>Range score (.2)</th>
<th>Size score (.2)</th>
<th>Status score (.4)</th>
<th>Research score (.1)</th>
<th>Protected area score (.1)</th>
<th>Weighted Conservation score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pelusios adansonii</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>4</td>
<td>6</td>
<td>4.6</td>
</tr>
<tr>
<td>Pelusios castaneus</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>13</td>
<td>6</td>
<td>5.5</td>
</tr>
<tr>
<td>Pelusios cupulatta</td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>4</td>
<td>6</td>
<td>4.0</td>
</tr>
<tr>
<td>Pelusios niger</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td>6</td>
<td>4.2</td>
</tr>
<tr>
<td><em>Pelomedusa subrufa</em> sensu lato</td>
<td>5*</td>
<td>4*</td>
<td>6</td>
<td>14</td>
<td>6</td>
<td>6.2</td>
</tr>
<tr>
<td><em>Pelomedusa variabilis</em></td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>6</td>
<td>4.2 using <em>P. subrufa</em> sensu lato research score 3.4 for <em>P. variabilis</em> alone</td>
</tr>
<tr>
<td>Pelomedusa olivacea</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>6.0 using <em>P. subrufa</em> sensu lato research score 5.1 for <em>P. olivacea</em> alone</td>
</tr>
<tr>
<td>Cyclanorbis elegans</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>1.1</td>
</tr>
<tr>
<td>Cyclanorbis senegalensis</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>6</td>
<td>3.4</td>
</tr>
<tr>
<td>Trionyx triunguis</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>11</td>
<td>6</td>
<td>3.9</td>
</tr>
<tr>
<td>Centrochelys sulcata</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>12</td>
<td>6</td>
<td>3.8</td>
</tr>
<tr>
<td>Kinixys eosa</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>13</td>
<td>6</td>
<td>3.9</td>
</tr>
<tr>
<td>Kinixys homeana</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>13</td>
<td>6</td>
<td>3.1</td>
</tr>
<tr>
<td>Kinixys nogueyi</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>7</td>
<td>6</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Note: Range score: Based on presumed historic range from TTWG (2021); <500 000 sq. km = 1 500 000–1 000 000 sq. km = 2, 1 000 001–2 000 000 sq. km = 3, 2 000 001–3 000 000 sq. km = 4, >3 000 000 sq. km = 5. *Range score for *Pelomedusa subrufa* sensu lato based on range map from TTWG (2014). Size score: Based on maximum carapace length of either sex from TTWG (2021); <20 cm = 4, 20–30 cm = 3, 30–40 cm = 2, >40 cm = 1. *Size score for *Pelomedusa subrufa* sensu lato (TTWG, 2014) based on maximum size of *Pelomedusa subrufa* sensu stricto in TTWG (2021). Status score: Based on the most recent TFTSG or IUCN threat level assessment (when different we accepted the more threatened status; CR = 1, EN = 2, VU = 3, DD = 3, NT = 5, LC/NE = 6. Research score: The number of research criteria from table 1 for which there is a published peer-reviewed article. Given the ongoing taxonomical debate regarding the genus *Pelomedusa*, we have included research scores for the recently monotypic species *P. subrufa* sensu lato as well as the presently recognized West African species, *P. variabilis* and *P. olivacea*. Protected area score: Presence in a protected area = 6, no known presence in a protected area = 0. Weighted Conservation score (maximum = 6.9): Accumulation of all other scores based on the following weights: Status score = 0.4, Range score = 0.2, Size score = 0.2, Research score = 0.1, Protected area score = 0.

Concern/Not Evaluated (LC/NE) = 6 (table 2).

As done by Forero-Medina et al. (2016) in view of the precautionary principle, we assigned the same score to species whose statuses were considered either VU or DD. Range size was scored using the ‘Presumed Historic Indigenous Range’ values provided by TTWG (2021) where a range size < 500 000 sq. km = 1 500 000–1 000 000 sq. km = 2, 1 000 001–2 000 000 sq. km = 3, 2 000 001–3 000 000 sq. km = 4, and > 3 000 000 sq. km = 5 (table 2). We used range size instead of endemism (used in Forero-Medina et al. (2016)) because there are no West African chelonian species restricted to a single country (TTWG, 2021) and because the concept of “endemism” has varying definitions (Amori and Luiselli, 2021). To assign scores for maximum size, where < 20 cm = 4, 20–30 cm = 3, 30–40 cm = 2, > 40 cm = 1, we used the ‘Max SCL’ values for the larger sex from TTWG (2021).
area a score of zero (table 2). In the text, the means are presented ± 1 Standard Deviation.

We then compared all species’ research and conservation priority scores to highlight and discuss the most critical knowledge gaps and conservation priorities. By increasing our knowledge of topics and species that have been historically neglected, we aim to improve the conservation trajectories for West Africa’s chelonians.

Results

Based on our literature search, the average research score for West African chelonians was 8.57 ± 3.76 out of 21 and the maximum score for any species was 13 (1; though Pelusios subufa sensu lato (TTWG, 2014) had a score of 14). No species had a score of zero, but three species had scores below five, including Cyclanorbis elegans, P. adansonii, and P. cupulatta. These are the species for which we know the least based on the used criteria, and thus they represent the highest research priorities in West Africa. The best-known species (each scoring 13), or the species who would be least prioritized by our research scores, were P. castaneus, K. erosa, and K. homeana. We repeat here that “research score” is distinct from the overall conservation priority score.

When the research scores were combined with maximum size, range size, threat status (IUCN or TFTSG), and presence in protected areas to create the overall conservation priority scores, the priority rankings were somewhat different. Though both Cyclanorbis elegans and P. castaneus remained at the top and bottom of the rankings, respectively, P. adansonii and K. homeana changed places. Pelusios adansonii moved into the top three lowest priority species and K. homeana (score = 3.1) received the second highest conservation priority score after Cyclanorbis elegans (score = 1.1). The average weighted conservation priority score was 4.0 ± 1.16 out of a possible 6.9 points (fig. 2). All non-marine West African turtle families had at least one species with a below average conservation score, meaning a high conservation priority. However, Trionychidae and Testudinidae were clearly the most prioritized groups in our analysis, with all species in these two families having below-average scores. These species were prioritized largely because of either low research scores or medium-high threat scores, though large size also played a role in the low scores of Trionyx triunguis, Cyclanorbis elegans, and C. sulcata, and to a lesser degree C. senegalensis and K. erosa. Cyclanorbis elegans, in addition to receiving the lowest research score, was the only species not known to be present in any nationally protected area.

---

**Figure 2.** Present state of published knowledge for all West African chelonian species (lower values represent greater priority for future research; maximum score is 21).
severely increasing its priority for conservation (Demaya et al., 2019). The five species with the lowest conservation priority in the region were all in the family Pelomedusidae and largely benefit from being small, widespread, and not very highly threatened (table 2, fig. 2). While *P. adansonii* represents a high priority for research (low research score), its high overall conservation score (low conservation priority) makes it an example of a species for which managers may have more time to research and then implement appropriate conservation actions.

When looking at the level of knowledge for each criterion, we found that geographical distribution was the most highly studied and the only criterion for which there was some level of knowledge for all species in the region (TTWG, 2021; TTWG maps have been previously used for a global assessment of chelonian conservation priorities, Ennen et al., 2020). However, we caution readers against assuming that there is no need for improving our knowledge of species distributions in West Africa (Wallacean shortfall; Lemolino, 2004). Surveys to extend known distributions as well as document species extirpations from historical localities are needed. *Cyclanorbis elegans*, for instance, has not been confirmed at any of its historical West African presence sites for decades (Baker, Diagne and Luiselli, 2015; Demaya et al., 2019). Other best-known criteria included relative abundance and phylogenetic rarity as well as quantification of habitat preferences and documented effects of humans (fig. 3). Similar to Forero-Medina et al. (2016) for chelonians in Colombia, the least-known criteria for West African species were longevity/age at maturity, followed by the number of clutches per year, the interannual nesting frequency, and studies of management units that reveal independence between populations through differences in allele frequencies (fig. 3; Moritz, 1994). These knowledge gaps reveal a lack of reproductive studies and long-term monitoring for West African species.

**Discussion**

Our results revealed a divergence between research and conservation priorities for West African chelonians. Overall, a relative lack of research was most evident for species in the family Pelomedusidae, whereas those in the family Testudinidae had the fewest knowledge gaps. However, this trend was reversed when comparing conservation priority, with Pelomedusidae representing the five lowest priority species, while four of the eight most threatened

![Weighted Conservation Priority Score](image-url)
species, according to our analysis, were Testudinids. Several biases can affect the research that scientists pursue, including costs, species threat level, ease of access, presence in the pet trade, and amount of effort needed to attain statistical power in analyses (Martin et al., 2012; Piccolo et al., 2020; Zvereva and Kozlov, 2021). In West Africa, logistical constraints and available funds are clear drivers of bias in field research. Testudinidae is a family of medium-large, charismatic species that are popular in the pet trade and face high levels of threat, all of which has likely boosted their coverage in the scientific literature. The one exception is Kinixys nogueyi, a relatively newly described West African endemic tortoise species (Kindler et al., 2012) in great need of intensified research efforts throughout its range (Segniagbeto et al., 2014). In fact, outside of publications on its’ geographical distribution, all seven research criteria for which at least some data have been provided for this species (fig. 4) are from just four publications (Luiselli, 2003; Kindler et al., 2012; Segniagbeto et al., 2015; Cayuela et al., 2019; we did not include the density estimate for Kinixys belliana from Nigeria (now K. nogueyi) provided in Luiselli (2006) as it was cited from Akani et al. (unpubl. report). Another group warranting high conservation priority are the soft-shelled turtles (Trionychidae), representing the first, third, and sixth most-threatened species (highest conservation priority) according to our analysis. Not only are these some of the least-studied (with the exception of T. triunguis, though see further discussion) and biggest species in Africa, they are also highly prized for their meat amongst domestic (Demaya et al., 2019; McGovern et al., 2021) and immigrant consumers (Luiselli et al., 2021d). Over-consumption is particularly a threat for the rarest turtle species in Africa, C. elegans (Luiselli et al., 2021d).

The presence of C. senegalensis (one of three Trionychids in our analyses and a species listed as VU by the IUCN; Diagne et al., 2016) near the top of our conservation priority analysis may be viewed as a potential shortcoming of our methodology when compared with the lower placement of species with EN statuses, such as K. erosa and C. sulcata (Luiselli and Diagne, 2014; Petrozzi et al., 2021). However, while C. senegalensis is known to be one of the more common species in many of the places it has been sampled (Senegal: McGovern, unpublished data; South Sudan: Demaya et al., 2019; Benin: Luiselli et al., 2020; Ghana: Gbewaa et al., 2021; Nigeria: Luiselli, Akani and Eniang, unpublished data) this is not the first analysis in which it has received a high threat ranking

![Figure 4](https://example.com/figure4.png)

**Figure 4.** Number of West African chelonian species with at least one article published on a chosen set of 21 research criteria (maximum number is 14 because we included Pelomedusa subrufa sensu lato; TTWG, 2014).
(Luiselli, 2009). In fact, Luiselli (2009), based on modeling six risk factors for all turtles in Sub-Saharan Africa, suggested *C. senegalensis* was the second most threatened of all five Trionychids in Africa (after *C. elegans*, also at the top of our conservation priority analysis) based largely on high “likelihood of human direct/indirect persecution” and high “habitat vulnerability.” This is a species that is often consumed, relatively large (Max SCL: 37.9 mm) and found in areas that are experiencing rapid population growth coupled with drastic habitat change (Luiselli, 2009). Combining these factors with a low research score reveals why our analysis included this species as a high conservation priority. We predict that this species may be prone to future declines should the present trends of exploitation and habitat loss continue unabated. Though this species may represent a disparity between current conservation priority and present population vulnerability, we stress that only through more research on this understudied species will managers be able to make informed conservation decisions on the sustainability of current exploitation, the true vulnerability of the species, and ultimately, the validity of our conservation priority ranking.

Another aspect of our analyses that may be considered as a limitation of this study is our decision to consider a criterion ‘covered’ if there was even a single study published on that topic (as done by Forero-Medina et al., 2016). The danger of this approach is that publications are variable in their breadth, rigor, and impact, often only providing data for a single population (Hall, Henry and Bunck, 1999), locality (Smith and Iverson, 2004), or season (e.g., Luiselli et al. (2006) provides ~80-day home ranges for *P. castaneus* and *P. niger*). There are also various types of publications; reviews, for example, are largely more general than single topic or single species studies. One example from our analysis of the potential effect of a single publication holding the same weight as a group of studies can be seen in publications on *C. sulcata*. Vetter (2005) suggested *C. sulcata* to be a generalist species of the Sahel, however, not until the publications of Petrozzi et al. (2018, 2019, 2020) did scientists get a better understanding of the specific habitat features preferentially selected by *C. sulcata* (i.e., ‘kori’ (seasonal streams), stabilized dunes, and herbaceous cover) and thus which landscape features are important for its conservation.

Additionally, many species in our analysis have large distributions, extending widely outside of West Africa (i.e., *T. triunguis, C. sulcata, P. adansonii*; TTWG, 2021), however we have included studies from throughout the entire extent of each species’ range. This presents the potential issue that findings for one population may be vastly different from those for another population in a different area, a situation which becomes even more likely when larger distances and diverse habitats are considered. These studies must be scrutinized for local relevance when using them to make conservation decisions. One species for which this may be particularly relevant is *T. triunguis*, a species which ranges from Senegal to Turkey and for which most studies have been carried out on Mediterranean populations (Oruc, 2001; Gidis et al., 2004; Corsini-Foka and Masseti, 2008; Akcinar and Taskavak, 2017; Candan, 2018, etc.). Additionally, genetic studies have suggested differentiation between African and Mediterranean *T. triunguis* populations (Guclu et al., 2011; Shanas et al., 2012), making it critical to augment research activities for this species in West Africa. West African *T. triunguis* populations have been considered for designation as a CR regional unit by the IUCN (van Dijk et al., 2017), and if we only included studies from West Africa in our research score analysis for this species, it would rank as the sixth least known and third highest conservation priority species in the region.

Regardless of these examples of why valuing a single study as equivalent to numerous studies on a single criterion may be a limitation of our analysis, we believe that our methodology allows for in-depth review of the validity and verity of studies included in our analysis.
and thus holds merit against analyses based only on keyword searches or total number of publications. Given the relatively small number of publications on West African chelonians, we were able to scrutinize and review each study in detail, allowing us to determine the credibility of the study as well as question the results before ultimate inclusion in our analyses (e.g., Lameed and Ayodele, 2010; Ogoanah and Omije, 2019; Umar et al., 2020).

From our research score analysis, as well as that of Forero-Medina et al. (2016), it is clear that much remains to be learned about turtles and tortoises (see Gibbons and Lovich, 2019). Just as three of the top four species of highest research priority in Colombia were from the cryptic, hard-to-detect, and seldom harvested family Chelidae (Forero-Medina et al., 2016), three of the top four least-known species in West Africa were also from the ecologically similar family Pelomedusidae (as an example, the TTWG species monograph for *P. adansonii* has only 15 citations, including magazine articles and unpublished reports, spanning from 1812–2006 (Bour, 2008)). Pelomedusidae are predominantly bottom-walking species that seldom bask, estivate for many months each year, are not locally favored by people for domestic consumption, and can be difficult to detect in certain habitats and during certain time periods, all of which decreases their likelihood of being studied. However, while other families have been easier to study and have enjoyed greater popularity amongst researchers, large knowledge gaps remain for all species. For example, not a single criterion (of those included in this review) needed to create a life history table (i.e., Longevity/generation time, Interannual nesting frequency, Number of clutches per year, Survival rate, Growth, Size or age at sexual maturity, Clutch size) is known for a majority of the species in this study. Specifically, longevity/generation time is unknown for most species (but see Cayuela et al., 2019 for *Kinixys*), while the number of clutches per season is only known for *P. subrufa* sensu lato (TTWG, 2014) from South Africa (now *Pelomedusa galeata*; Strydom, 2001), a climate greatly differing from conditions in West Africa. While these life history table parameters are some of the least-known criteria, they are also the most vital for creating effective conservation initiatives.

Evidently, our criteria were not all-encompassing when planning successful long-term conservation. As an example, we did not include studies of thermal ecology (see Luiselli, 2005 for *Kinixys* thermal ecology), which is increasingly becoming an important criterion alongside a warming climate, yet one which has largely been overlooked to-date. As threats, climates, and habitats change, so will the research and conservation priorities needed to combat them.

Regarding the two West African *Pelomedusa*, Vargas-Ramirez et al. (2016) mentioned both *P. olivacea* and *P. variabilis* as two of the six least sampled species in the genus and called for increased data collection for these taxa, corroborating our findings of low research scores (high research priority) for both species. Similarly, Masin et al. (2014), in their review of the most potentially invasive turtle species in Europe, lamented the lack of knowledge for the entire *Pelomedusa subrufa* complex, specifically in regard to our criterion of size or age at sexual maturity, stating that they “did not find information on age at maturity in *Pelomedusa* subrufa” (our literature search revealed that size or age at sexual maturity has only been provided for *P. galeata* by Strydom (2001)). This is particularly glaring given that *Pelomedusa subrufa* sensu lato (which includes *P. galeata*; TTWG, 2014) received a higher research score than all other species in our analysis. Without these basic data for many West African chelonians, conservation actions are hindered and restricted to broad strategies such as land protection and reduction of anthropogenic threats (i.e., over-harvesting, habitat degradation, etc.).
And while these actions are undoubtedly beneficial to many species, a lack of detailed knowledge on the specific habitats used throughout the life cycle of a species or perhaps the presence of locally adapted populations within wide-ranging species (e.g., Stuckas et al., 2014), may result in extirpations or eventual extinctions of understudied taxa. By increasing our knowledge on West Africa’s chelonians, conservationists will be able to better prioritize and structure conservation practices.

Recommendations

There are many approaches to outlining conservation priorities, varying widely based on expertise, funding, habitat, and scale. The approach used in this review (adapted from Forero-Medina et al., 2016) is meant to draw attention to the understudied species and topics for West African chelonians to stimulate research and thus better inform conservation. Many of the highest conservation priority species recognized by our analysis have been highlighted as species needing conservation attention in previous analyses (Luiselli, 2009; Bombi et al., 2011, 2013; Segniagbeto et al., 2014). We have corroborated these recommendations and coupled them with research priorities that, when executed, will better prepare conservationists to make difficult conservation decisions. Segniagbeto et al. (2014) found that *K. erosa* and *K. homeana* had the highest threat estimates of all chelonians in Togo using an expert-based assessment. Similarly, both species had above average conservation need in our analysis, lending weight to our methods but also highlighting the importance of country-by-country threat assessments and the potential of these assessments to inform country-based conservation actions. We recommend other countries follow suit in assessing the species-specific conservation needs in their countries to help focus attention where it is most critical. These two forest *Kinixys* species also provide a great example of high-efficiency research. Nearly all publications for *K. homeana* include concomitantly collected data for the often-sympatric *K. erosa*, greatly improving our knowledge of the turtle community as a whole but also of each species individually. This impactful and opportunistic method of data collection should be executed for other sympatric species to increase efficiency, save funds, and augment our overall knowledge of these species and their potential interactions. It is our belief that increased research will improve awareness and advance conservation for chelonians in West Africa and this priority analysis is our attempt to stimulate these advances.

Acknowledgements. The authors would like to thank Drs. John Iverson and Jeffrey Lovich for providing valuable publications during our literature search.

References


